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Conspicuous vermic characters in mountain soils developed by large lumbricids (Oligochaeta)

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In limestone areas of the Carpathians, earthworm communities occur dominated by very large lumbricids such as *Octodrilus aporus, O. friwaldszkyi, O. permagnus* or *Allolobophora robusta*. These species develop conspicuous vermic characters in soils evolved mainly on limestone, more rarely on the neighbouring acid soils. Therefore, soils developed on different parent materials and usually classified into different classes, exhibit quite similar structures and chemical properties of the upper horizons. Complex data on soil morphology, physical and chemical properties as well as the species structure of the inhabiting earthworm communities, allow the discrimination of new vermic subtypes in mountain rendzina (Mollisols), brown earth, terra rossa (Cambisols) and podzolic brown soil (Spodosols). Vermic subtypes have been recorded so far only from Mollisols.

1. Introduction

The prominent role of soil fauna in the pedogenetical processes, mainly through its effects on the morphology of soil profile, and the breakdown of organic residues, is well known. However, the faunal activity is only little considered in soil systematics. Nevertheless, there are situations when the activity of certain groups of organisms are so overwhelming that they should be considered in soil taxonomy, too. Such is the term "vermic" introduced in soil systematics by the American "7th Approximation, 1960" to indicate soils intensively processed by soil fauna, especially by earthworms. According to the Romanian system of soil classification (1979) the "vermic character" designates soils that exhibit coprolites (casts of earthworms or other soil animals) and earthworm burrows (sometimes filled with soil material) in more than 50% of the volume of the A horizon, and in more than 25% of volume of the subsequent horizon. It is a morphological viewpoint which concerns the upper part of the soil profile as a whole. As we pointed out (Pop & Postolache 1987) the term "vermic" should be used to indicate visible, morphologically stable and lasting aggregates and burrows built up by soil fauna. Micromorphologically the activity of soil fauna can be observed in all evolved soils. Kubiena (1953) when defining mull, showed that "practically all soil aggregates are earthworm casts or residues of them".

The "vermic characters" are not generally accepted in the present soil classifications. Nevertheless, our opinion is that we should taxonomically discriminate the soils with conspicuous vermic characters. The "vermic character" has been so far considered diagnostic only for a few soil types, like chernozems in the class of mollisols. In addition, morphologic and micromorphologic studies allowed us (Pop & Postolache, 1987) to distinguish a new vermic cambic rendzina processed by an earthworm community dominated by the large *Octodrilus frivaldszkyi*.

The largest lumbricid species known (assigned to the genera *Octodrilus* and *Allolobophora*) occur in insularly distributed limestone areas of the Carpathians. The peculiarities of these species, as well as their unusually intense activity in soil have been in our attention for more then 10 years. New species of the genus *Octodrilus* were described by Pop (1989). Laboratory studies revealed aspects of the role played by *O. frivaldszkyi* and *O. bihariensis* in pedogenetical processes (Pop et al. 1992).

Meanwhile, field studies showed that conspicuous vermic characters occur not only in soils developed on limestone but also in the neighbouring acid soils, when large lumbricids are present.

This paper presents earthworm communities that develop quite similar vermic characters, and account for a process of convergent evolution of the soil profile in three different soil types, namely in rendzina (Mollisols), brown earth (Cambisols) and podzolic brown soil (Spodosols). As we have no knowledge of previous special studies on the chemical and physical peculiarities of the vermic soils, our analytical data will be presented as genuine.

2. Material and methods

2.1. Study sites

The following three sites were studied: (1) Padis, the Apuseni Mts, (the Carpathians) 1300 m alt., beech forest, vermic cambic rendzina on dolomitic limestone; (2) Buces Vulcan, the Apuseni Mts, 550 m alt., beech forest, cambic eubasic brown earth on volcanic breccia with quartz, calcite and andesite; (3) Abrud, Dealul Mare, the Apuseni Mts, 800 m alt., beech forest,vermic podzolic brown soil on orthogneiss and schists.

2.2. Soil research

The vermic characters have been established in field by morphologic study of soil profile. Soil horizon designation according to the Romanian system of soil classification (1979). The analytical approach is designed to detect ionic equilibria between soil solution and solid phase of the soil, using a chemical methodology only partially published (Vasu 1985, 1988).

3. Results and discussion

3.1. Earthworm communities

The investigated vermic soils are inhabited by earthworm communities dominated by very large species of the genera *Octodrilus* and *Allolobophora*. As these giant lumbricids have been reported only from the Carpathians, their body sizes are presented in Table 1.

The giant lumbricid species are vicariants, one of the *Octodrilus* species occurring in the Apuseni Mts and *Allolobophora robusta* in the South Carpathians. Other 4 to 6 smaller species cohabit with these species (Table 2). As a rule, the community includes species of all ecological types, namely epigeic, endogeic and anecique forms. Nevertheless, the small, redpigmented epigeic litter dwellers (*L. rubellus*, *D. alpina*) are relatively scarce, but *D. byblica* is very characteristic. It seems that they are outcompeted by the large litter consuming anecique *Octodrilus* species and by *L. polyphemus*. Among the endogeic species, *A. dacica*, *O. lacteum* and *O. compromissus* are the most frequently found. This type of community has been referred to as "Synusia with *Lumbricus polyphemus* – *Octodrilus friwaldszkyi*" (Pop 1985) or as "Synusia with *L. polyphemus*" (Pop 1987).

Quantitative data on the earthworm communities in the three vermic soils dealt with are given in Table 2. The density as well as the biomass are highest in rendzina, lower in the brown earth and less than half in the podzolic brown soil. In all communities, the large *Octodrilus* species dominate not only in biomass (85–92%) but also in density (29–48%).

3.2. Soils

Our field research showed that vermic characters occur as a rule in soils developed on limestone, but sometimes also in the neighbouring acid soils, when the large *Octodrilus* species are present. Thus, vermic subtypes could be discriminated in rendzinas (Mollisols), eubasic, mesobasic and argillic brown earth, terra rossa (Cambisols) and even in podzolic brown soils (Spodosols). Here only one soil type from each class is disscused.

Table 1. Body sizes (mm, g) of the largest lumbricids in the Carpathians. Worms preserved in 4% formalin.

	Length	Diameter	Mass
Allolobophora robusta	300–1100	8–18	30–90
Octodrilus aporus	207–415	9–14	37–52
Octodrilus friwaldszkyi	180–460	9–14	14–37
Octodrilus ophiomorphus	225–420	12–15	20–48
Octodrilus permagnus	320–720	13–14	35–76

Table 2. Proportion (%) of total density (D) and biomass (B) of lumbricid species in three vermic soils from the Carhathians.

Soil:	Cambic rendzina		Brown earth		Podzolic brown soil	
Site and date:	1-Padis, 16.08.79		2-Buces Vulcan, 6.06.72		3-Abrud, 12.06.92	
	D	B	D	B	D	B
Allolobophora dacica (Pop, 1938)	.	.	26.5	2.2	13.9	1.7
Dendrobaena alpina (Rosa,1884)	12.1	0.8	.	.	.	
D. byblica (Rosa, 1893)	22.7	1.2	4.4	0.4	25.0	1.5
D. clujensis Pop, 1938	2.2	6.0	.	.	22.2	6.6
Lumbricus polyphemus (Fitz.,1883)	.	.	1.5	0.3	.	.
Octolasium lacteum (Orley, 1885)	.	.	2.9	0.6	5.6	0.4
Octodrilus aporus V.V.Pop, 1989	.	.	48.5	92.5	.	.
O. bihariensis V.V.Pop, 1989	15.2	7.0	.	.	.	.
O. compromissus Zicsi & V.V.Pop, 1984	.	.	11.8	1.7	.	.
O. exacystis (Rosa, 1896)	.	.	4.4	2.3	.	.
O. frivaldszkyi (Orley, 1880)	28.8	85.0	.	.	.	.
O. permagnus V.V.Pop, 1989	.	.	.	.	33.3	89.8
Total community / m^2	66	257 g	34	200 g	18	98 g

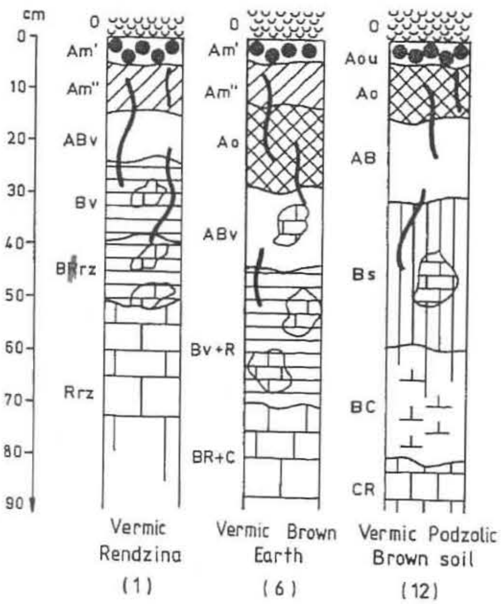

Fig. 1. Profile of three vermic soils from the Carpathian Mountains. Horizon designation: Ao = ochric A horizon; Am = mollic A horizon; Au = umbric A horizon; Bv = cambic B horizon; Bs = spodic B horizon; Brz = rendzinic B horizon; C = unconsolidated mineral horizon; R = compact rocks.

Morphology of vermic soils

The investigated soils are rather shallow, with a depth of 50–60 cm in rendzina, 70–80 cm in brown earth and 50–60 cm in the podzolic brown soil (Fig. 1). Coarse rocky fragments occur scarcely in A horizons but up to 10–20% in AB and more than 40–50% in B horizons.

The most characteristic feature of these soils is the presence of a thick (4–6 cm) surface layer of discrete, stable and large (2–5 cm in diameter) wormcasts. The earthworm cast strata (Am' and Aou in Fig. 1) consist of old, hardened and rounded casts, not linked or compressed together, as well as of fresh casts, mostly as conical heaps. Such a fresh heap can weight as much as 200–300 g (oven dried). Large amounts of soil material from deeper horizons are brought to the surface, burying the former cast horizon.

The size of structural elements in the soil (burrows and casts) depends on the size of worms, i.e they are species specific but their stability or degradation is conditioned by the physico–chemical properties and the texture of the soil. In rendzina the vermic structure is more stable than in acid brown soil where the casts are rapidly broken down (Pop et al. 1992).

In the deeper horizons the diameter of worm casts diminishes.The spongy microstructure caused by mesofauna, very characteristic for the upper horizons, also diminishes, and the horizons look more compact. However, as micromorphological studies have showed, the wormcast structure does not totally disappear even in deeper horizons (Pop & Postolache 1987). The A horizons have a crumb structure and the AB and B horizons an angular blocky structure. Earthworm burrows with a diameter up to 1.5 cm occur in the entire soil profile.

Physical and chemical properties of the soil

The physical and chemical properties exhibited by the 3 investigated soils are normal for their evolutionary stages and the given pedoclimatical conditions (Tables 3, 4 and 5).

The earthworms have affected foremost the morphology of the soil profile but their biochemical activity should not be neglected, even if we do not understand it entirely.

Nevertheless, there are some peculiarities which bring together these soils showing a somewhat convergent evolution. These common features occurring in different soils should be considered as a result of an unusually intense earthworm activity. A very low bulk density, especially in the surface horizons (0.4–0.7 g/cm^3) as well as low resistence to penetration (1–6 kgf/cm^2) associated with a high permeability (290–1280 mm/h) and very high porosity (over 50–60%) give the frame of peculiar biochemical processes in these vermic soils.

The thermodynamic stability conditions showed by values of the oxydoreduction potential (Eh) between 400–600 mV (that is 100–200 mV higher than in typical soils) in the condition of higher humidity than usual (Wi = 53–65%) show very high oxidative processes, due to the very aerated vermic structure of the soil.

Table 3. Particle size distribution and organic compounds in three vermic soils. — Ht = total humus; CH = humic acid carbon; CF = fulvic acid carbon.

Horizon	Depth cm	Clay <0.002 %	Coarse sand 2.0–0.2%	Ht %	CH/CF	C/N
Vermic cambic rendzina (1 - Padis)						
Am'	0–5	34.0	0.1	5.86	0.8	5
Am''	5–15	41.3	0.1	3.40	1.4	8
AB	15–24	42.8	0.0	3.63	0.9	5
Bv	26–35	45.5	0.9	5.50	1.3	7
Brz	40–50	57.4	0.0	9.18	1.0	10
Vermic brown earth (2 - Buces Vulcan)						
Am'	0–4	19.0	57.1	11.30	1.6	10
Am''	4–10	19.3	57.9	12.19	1.1	14
Ao	15–25	20.4	56.0	3.85	0.8	6
ABv	30–40	18.9	58.5	4.68	1.7	ND
Bv+R	50–60	21.3	52.5	4.25	1.2	ND
Vermic podzolic brown soil (3 - Abrud)						
Aou	0–4	26.7	7.8	8.70	0.5	8
Ao	5–15	29.5	8.8	4.24	1.7	4
AB	15–25	33.6	6.8	3.23	0.5	ND
Bs	35–45	33.6	5.9	1.26	0.6	ND
BC	65–75	27.9	5.2	0.82	0.3	ND

The humus content is very high (4–6% in rendzina, 4–11% in brown earth and 4–8% in podzolic brown soil). In all cases, the humification processes are directed toward fulvicisation, a most unusual process in saturated soils. This process is indicated by the relatively high values of carbon in fulvic acids (CF = 300–600 mg/100 g soil) and especially by the ratio between humic and fulvic acid carbon which is mainly below unit (0.5–0.9) or slightly over (1.1–1.4).

Table 4. Stability conditions in three vermic soils. — Eh = electrod potential; Wi = humidity; S = total exchangeable bases; Te = cation-exchange capacity; V % = degree of base saturation at pH = 8.3.

Horizon	Depth cm	pH	Eh mV	Wi % vol.	me/100 g soil S	me/100 g soil Te	V %
Vermic cambic rendzina (Padis)							
Am'	0–5	7.13	456	60.8	56.8	56.8	93
Am"	5–15	7.08	455	64.9	50.1	50.1	90
AB	15–24	6.98	483	61.0	29.4	29.4	87
Bv	26–35	7.12	454	55.7	27.2	27.2	84
Brz	40–50	7.40	444	54.1	61.9	61.9	92
Vermic brown earth (Buces Vulcan)							
Am'	0–4	6.80	506	53.6	33.2	33.2	90
Am"	4–10	6.63	394	57.2	26.3	26.3	85
Ao	15–25	5.68	456	46.3	16.5	16.5	85
ABv	30–40	6.75	464	45.2	20.6	20.6	92
Bv+R	50–60	7.12	492	50.1	21.5	21.5	90
Vermic podzolic brown soil (Abrud)							
Aou	0–4	5.04	564	53.0	15.47	17.34	52
Ao	5–15	4.48	596	56.4	5.72	10.58	29
AB	15–25	4.40	606	54.7	4.26	10.19	24
Bs	35–45	4.38	634	53.7	4.27	11.12	24
Bc	65–75	4.60	626	51.9	4.25	9.46	28

Table 5. Elements (water soluble / mobile, ppm) from mobile structure of three vermic soils (depth in cm).

Horizon	Depth	Ca	Mg	Fe	Al
Vermic cambic rendzina (Padis)					
Am'	0–5	170/9424	83/2320	2/128	5/0
Am"	5–15	151/7934	81/2502	3/128	2/0
AB	15–24	73/5314	37/1758	7/142	13/0
Bv	25–35	16/61728	7/1512	4/188	1/0
Brz	40–50	27/19242	12/4710	4/224	30/0
Vermic brown earth (Buces Vulcan)					
Am'	0–4	85/98	8/70	10/522	11/0
Am"	4–10	75/126	6/68	3/421	18/0
Ao	15–25	12/52	5/72	18/724	35/0
ABv	30–40	36/109	4/42	15/498	80/0
Bv+R	50–60	44/112	5/79	15/454	38/0
Vermic podzolic brown soil (Abrud)					
Aou	0–4	10/117	4/194	16/831	34/145
Ao	5–15	3/24	3/74	18/441	35/430
AB	15–25	4/14	1/52	1/395	7/513
Bs	35–45	4/10	2/39	8/504	13/617
BC	65–75	2/11	1/63	1/444	6/444

The presence of ionizate Al (2–80 ppm) and of ionisable SiO_2 (50–300 ppm) in the soil solution of a saturated soil ensures suitable conditions for the formation of Al–fulvate and Al–silicate gels. As our experiment poited out, these are very efficient binding materials during soil structuring processes. Differences in the base and in Al and Fe iones content as well as in the texture account for differences in stability of soil agreggates in the three investigated soils.

4. Conclusions

Large *Octodrilus* and *Allolobophora* species, occurring in limestone areas of the Carpathians, build up conspicuous vermic characters in soils, not yet recorded in the Northern temperate zone. Due to the overwhelming earthworm activity, the upper part of the profile of soils included in different classes, such as rendzina (Mollisols), brown earth and terra rossa (Cambisols) and podzolic brown soil (Spodosols) undergo convergent evolution.

The most striking character of these soils is the development of a 4 to 6 cm thick surface layer of discrete, stable and large (2–5 cm) earthworm casts as well as a large burrow system in the soil profile.

The highly aerated conditions, in the presence of marked earthworm activity, also influence the chemical properties of the soils, leading to somewhat analogous processes, like the fulvicisation of humus and the composition of cementing material of the soil aggregates.

The morphology, micromorphology, and the physical and chemical properties of these soils, allow the discrimination of new vermic subtypes in mountain rendzina, brown earth as well as in podzolic brown soil, each as a result of the high pedogenetic activity of the soil fauna, dominated by large earthworms.

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